Study of Geometric Effect on Phase Change Random Access Memory

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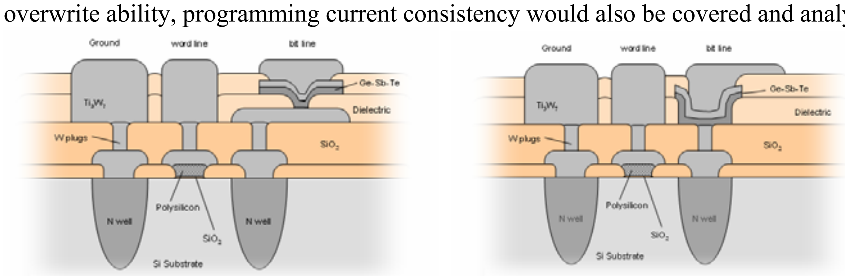
Abstract

Phase change random access memory (PCRAM) is a promising non-volatile memory (NVM) technology with high performance and low cost. Induced by electrical pulses, the phase change material switches between its high resistance amorphous and low resistance crystalline states. Though PCRAM offers much promise, there are still certain technical problems that need to be solved. One of the main challenges for PCRAM is reduction of programming current. Engineering PCRAM structure is one of the efficient approaches. In this paper, we compared PCRAM memory devices with two different geometrical configurations by simulation and experiments.

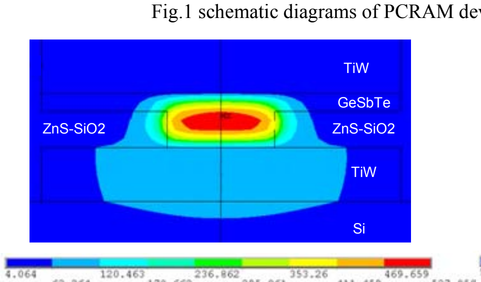
Figures 1(a) and (b) show schematic diagrams of two different cell configurations for the PCRAM devices integrating with CMOS transistor. The contact area between the phase change materials and the bottom electrode is designed with the same size. As can be seen clearly in Fig. 1(a), the amount of phase change material above the contact area is surrounded by dielectric layer while it is not in Fig. 1(b). In PCRAM devices, GeSbTe alloy was used as the recording material, ZnS-SiO2 as isolation material and TiW as electrode material. Effects of material properties, structural stack and geometrical configurations on device performance were investigated through thermal and electrical analysis. Simulation studies were carried out by applying electrical pulse with a constant voltage. Both voltage and pulse width were varied. In operation, the phase change is induced by heating though Joule effect. Hence, if the heat generated can be confined in the active area, such PCRAM device will be more efficient. The temperature distribution, the achievable highest temperature and the location of highest temperature point were simulated and analysis for the two PCRAM devices, respectively. Fig. 2 shows the temperature distribution after applying same voltage value pulses in the two devices with different cell configurations, respectively. It can be found that heat was confined mainly in the phase change materials, which is consistent with previous report [1]. Furthermore, both the bottom electrode size and its thermal conductance and the interface between the phase change material and the bottom electrode were also determinant factors to the temperature profile and heat distribution.

Beside simulation results, 128bits PCRAM arrays with abovementioned cell structures as shown in Fig. 1 were fabricated and tested respectively. CMOS transistor was used as the addressing element. The arrays had circuit functions including decoding, read/write and control circuit. Devices performance including resistance-current (R-I) curve, RESET/SET programming currents, I-V curves were measured. For example, Fig.3 shows R-I curve for the two types of PCRAM devices. It can be seen that integrated PCRAM with the Type II structure exhibited lower RESET current but a wider current range for switching from SET state to fully RESET state than the device with the Type I structure. Relevant detailed simulation and experimental analysis will be presented in the conference. Beside these results, issues regarding RESET/SET overwrite ability, programming current consistency would also be covered and analyzed.



(a) (b)

Fig.1 schematic diagrams of PCRAM device with structure of (a) Type I, (b) Type II integration with CMOS



(a) (b)

Fig.2 Temperature distribution in PCRAM with structure of (a) Type I, (b) Type II

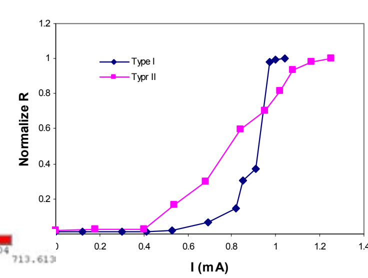


Fig.3 R-I curves for PCRAM with two structures

Reference:

[1] E. Varesi, A. Modelli, P. Besana, T. Marangon, F. Pellizzer, A. Pirovano, R. Bez "Advances in phase change memory technology" EPCOS 2005